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Effect of 9.6-GHz Pulsed Microwaves on the Orb Web Spinning Ability of the Cross Spider (*Araneus diadematus*)

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Eight cross spiders (*Araneus diadematus*) were exposed overnight (16 h) during web-building activity to pulsed 9.6-GHz microwaves at average power densities of 10, 1, and 0.1 mW/cm² (estimated SARs 40, 4, and 0.4 mW/g). Under these conditions, 9.6-GHz pulsed microwaves did not affect the web-spinning ability of the cross spider.

Key words: microwaves, spider webs, behavior, 9.6-GHz pulsed radiation

There is considerable controversy as to whether microwave irradiation at low levels affects the central nervous system. The eastern European literature contains reports of alterations of the nervous system and behavior of mammals at low levels, but western scientists have generally been unable to duplicate these effects [McRee, 1979]. The ability of the cross spider to spin an orb web is altered by many drugs that affect the central nervous system (CNS), and therefore it can be used as a screening test for the CNS activity of drugs [Witt and Reed, 1965]. We employed the web-spinning ability of the spider to investigate the effect of microwaves on CNS function.

The female cross spider (*Araneus diadematus*) was chosen because it is one of the few spiders that builds a new web nearly every night. Spiders were hatched in our laboratory from a cocoon (purchased from Mr. Leonard Pankhurst, Canastota, NY), and were raised in the manner described by Witt [1971], being fed mature drosophila while they were young, and mature house flies (2-4/week) as adults. The spiders were transferred to plastic frames when they were fully grown (fourth molt). The frames, which were used for sham and microwave exposures, were constructed of Plexiglas®. The outside frame support was made of 0.95-by-1.27-cm strips of plastic. The front and back panels were made of 0.32-cm plastic and were removable for feeding and for photographing the webs. The base was also made of 0.32-cm plastic,

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and the top and sides were covered with fiberglass screening for ventilation. The overall dimensions were 45 cm high $\times$ 33 cm wide $\times$ 7 cm deep.

Exposures took place in an environmentally controlled (22°C and 50% relative humidity) compartment made of Styrofoam® in a microwave anechoic chamber [described by Liddle et al, 1980]; a similar sham-exposure chamber was located nearby. All exposures were conducted at 9.6 GHz, which is close to the calculated resonant frequency of 10.2 GHz. The animals were exposed overnight at an average power density of 10, 1, or 0.1 mW/cm² (pulse repetition rate, 970–1,000 pulse per second; pulse width, 1.0 μ s). The estimated SAR at 1 mW/cm², based on a prolate spheroidal model, is 4 mW/g (based on a 1.5 $\times$ 0.24 cm spheroid [see Durney et al, 1978]). Power density was measured at a point 15 cm from the top of the plexiglas cage, which is the approximate position of the spider in the center of a web. At the top of the cage, power density may have been increased by as much as 34%, and at the bottom of the cage it may have been decreased by as much as 60%.

Eight spiders were exposed at 10 mW/cm². Only one animal at a time was irradiated. If the cage contained an existing web, it was cut down, except for one top-to-bottom connection, and left in the cage for the spider to ingest and reutilize. The spider in its cage was then placed in the microwave chamber overnight and sham-exposed with the microwave generator turned on, but at zero power level. The resultant web was photographed the following morning and labelled as the preexposure web. That evening the web was again cut down, and the spider was exposed at 10 mW/cm² overnight so that the web was spun while the animal was being irradiated. The new web was photographed the following morning. The lights were turned on in the chamber at the same time each morning, and the exposure was continued for an additional 1.5 hours, as spiders of the species used typically spin their webs around sunrise and take ~45 min to 1 h to complete a web. The same spiders that were exposed at 10 mW/cm² were exposed at 1 and 0.1 mW/cm². A minimum of three months elapsed before exposing a spider at a lower power density.

The webs were measured, and the results were calculated as described by Witt et al [1968]. The webs were photographed, and measurements were made from an actual size print of the web. In brief, the angle of each radius was measured, as well as the distance from the center to the first spiral thread, the outermost spiral thread, and the nearest frame thread. In addition, the distance to each spiral thread was measured along the four cardinal compass directions to calculate the mesh width, and the four compass directions were measured to calculate the symmetry of the web.

The calculation of the web parameters as described by Witt et al [1968] results in 27 numerical values that describe various aspects of the web. In a more recent publication, Witt and his coworkers [Reed et al, 1982] presented a way of analyzing these various parameters of the web by categorizing and grouping the results into five different features. These features were (1) thread elements, (2) size, (3) regularity, (4) mesh density, and (5) shape. To analyze our data, a representative parameter was chosen for each of these features. Thus, the number of radii was chosen to represent the thread elements, the spiral (catching) area representing size, the angle regularity (differences between adjacent angles) representing regularity, mesh width (number of spirals per cm²) representing mesh density, and the ratio of the width to length representing shape. The differences between preexposure and exposure values for the five parameters were analyzed with the aid of multivariate techniques in order to determine whether these changes, viewed jointly, were different from zero. A separate analysis was performed at each power density.

The results of the 9.6-GHz exposures on the five measured parameters at the three power densities are shown in Table 1. The multivariate analysis of the five parameters at 10 mW/cm² indicated no overall significant difference between exposure and preexposure values ($P = 0.361$), nor were any of the individual t-tests significant. Figure 1 shows two webs from the same spider; one was spun while the spider was in the exposure chamber with no microwaves (A—0 mW/cm²), and the second was spun the following night during exposure at 10 mW/cm² (B).

Also shown in Figure 1C is a web spun in our laboratory by a spider 12 h after receiving d-amphetamine (600 mg/Kg orally) as an example of the types of changes that can be expected from some drugs that affect the CNS.

The overall multivariate analyses for the spiders exposed at 1 mW/cm² also indicated no overall change in these five parameters ($P = .761$). None of the individual t-test probabilities were significant.

Because of one missing mesh-width value for one spider in the 0.1-mW/cm² group, the data was analyzed for only four parameters for all eight animals, and for all five parameters for seven animals. The multivariate test for the four parameters for eight animals was marginally significant ($P = .06$), and the individual t-tests indicated that the number of radii was marginally significantly greater ($P = .049$) and the angle regularity almost significantly less ($P = .055$) following exposure as compared to the preexposure values. When all five parameters were analyzed jointly for seven animals, the multivariate analysis was not significant ($P = .34$).

Web-building frequency was also analyzed, as some drugs (eg, chlorpromazine) interfere with the web-building drive, but do not affect the basic size or shape. The frequency of web building was analyzed separately for each power density by Fisher's exact test for probabilities. At 10 mW/cm², five spiders spun a web the first day, one the second day, and two the third day as compared to six, one, and one for the first, second, and third days for the preexposure webs. At 1 mW/cm², seven spiders in both groups spun a web on the first day and one on the second day. At 0.1 mW/cm²,

TABLE 1. Comparison of Orb Webs Spun by *A. diadematus* Spiders During Irradiation by Pulsed 9.6-GHz Microwaves at 10, 1.0, and 0.1 mW/cm² With Preexposure Webs (N = 8)

Measurement	Power density (mW/cm ²)	Preexposure value ($\bar{X} \pm SD$)	Exposure value ($\bar{X} \pm SD$)	P
No. of radii	10	28.5 $\pm$ 2.1	28.9 $\pm$ 2.7	0.670
	1	24.6 $\pm$ 4.3	25.5 $\pm$ 3.5	0.596
	0.1	22.9 $\pm$ 3.9	24.1 $\pm$ 2.7	0.049
Spiral area (catching) (cm ²)	10	364.8 $\pm$ 62.8	389.7 $\pm$ 52.0	0.313
	1	318.0 $\pm$ 103.4	336.0 $\pm$ 87.2	0.637
	0.1	300.1 $\pm$ 103.6	326.8 $\pm$ 86.2	0.235
Angle regularity	10	3.51 $\pm$ 1.12	3.96 $\pm$ 1.21	0.443
	1	4.72 $\pm$ 1.55	4.26 $\pm$ 1.45	0.379
	0.1	5.70 $\pm$ 1.78	4.18 $\pm$ 1.39	0.055
Mesh width	10	38.8 $\pm$ 8.5	41.1 $\pm$ 9.6	0.495
	1	45.4 $\pm$ 9.1	45.8 $\pm$ 14.2	0.931
	0.1	53.6 $\pm$ 18.4	47.6 $\pm$ 12.0 ^a	0.336
Ratio/width:length	10	0.93 $\pm$ 0.07	0.92 $\pm$ 0.19	0.871
	1	0.93 $\pm$ 0.12	0.84 $\pm$ 0.07	0.097
	0.1	0.87 $\pm$ 0.06	0.89 $\pm$ 0.07	0.990

^aN = 7.

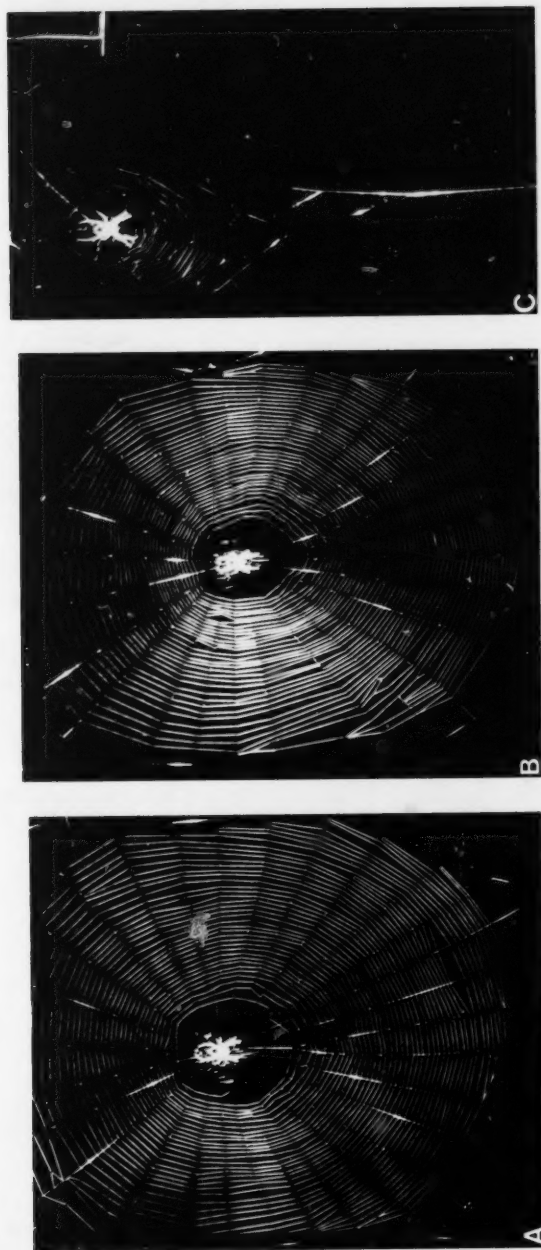


Fig. 1. A. Web spun at 0 mW/cm². B. Web spun by the same spider the following night during exposure at 10 mW/cm². Both webs are normal and similar in size and shape. C. This web was spun in our laboratory by a spider that was not used in the study, 12 h after receiving d-amphetamine (600 mg/Kg orally), showing a much smaller web with considerable angle irregularity. All three photographs were reduced for publication, but are based on the same scale.

the values were six, one, and one for the exposed, and seven and one for the preexposed values. When compared to controls, there was no difference in the frequency of web building in any of the groups ($P = .5$, $.4$, and $.5$, respectively, at 10, 1, and 0.1 mW/cm²).

The use of the orb-weaving ability of the cross spider provides a unique way of looking at the effects of microwave exposure on the CNS. Several particularly appealing aspects of this study are that (1) the animal is tested for its ability to perform a complicated task during microwave exposure rather than being tested for performance after the exposure has been completed; (2) it is not necessary to introduce any additional test equipment into the microwave field; and (3) the animal is in familiar surroundings—ie, the frame or cage in which it has been living in the laboratory is placed directly in the exposure chamber. In addition, the actual test analysis can be performed after the exposures are completed, and a permanent photographic record of the results is obtained.

In the present study, there were no statistically detectable alterations in the web patterns or the web-spinning ability of the spiders following exposures at 10 or 1 mW/cm². The statistical analysis of the results at 0.1 mW/cm² suggested that there may be a difference in two of the parameters. The number of radii was higher in the exposed webs than in the preexposed webs, with the difference being just significant, and the angle regularity value was lower in the exposed animals, the difference being almost significant. A closer analysis of the data indicates that, for the number of radii, the preexposure values are lower than the preexposure values at the other two power densities, and that the number of radii for the webs spun during exposure are more similar to the values of the other groups. The same situation exists with the value for angle regularity, in which the preexposure value is high relative to the other groups. Thus it appears that this significance was spurious and that webs spun during exposure at 0.1 mW/cm² were also not altered as a result of the microwave exposure. These results indicate that there is no CNS effect in cross spiders at this frequency and these power densities.

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